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Creating a smart application system to provide a beneficial maintenance service for elderly drivers

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Abstract. As overall population ages, elderly drivers have become a larger percentage of the driving population. With this trend, a lot of vehicle systems have been improved for elderly's safety and convenience using different advanced technologies. However, elderly drivers have often paid more money than other drivers in a car-repair shop due to their lack of knowledge about vehicle systems with modern technologies. Given this fact, developing a tool to diminish this disadvantage and to help elderly drivers maintain their cars with confidence and with minimal cost is necessary. Therefore, this research work mainly focuses on suggesting a system concept on user-interface application, which is connected to a smart phone or a tablet to provide beneficial services anywhere. For the research outcome, diverse research activities – surveys, interviews with small focus groups, observations of the focus groups, and discussions – has been conducted to understand the elderly driver's difficulties and behaviours regarding vehicle maintenance, to investigate what specific problems make them uncomfortable in repair shops, and to demonstrate how new system-concepts could be developed for the elderly. Furthermore, we conclude that adequate system-concepts for the elderly would offer elderly drivers convenient vehicle repair and maintenance and provide them a confident driving experience.

1 Introduction

In recent decades, elderly drivers have become a larger percentage of the driving population as the aging population increases worldwide. A report compiled for the National Highway Traffic Safety Administration (NHTSA) says that 36.8 million licensed drivers were age 65 and older in the United States in 2013 [15]. By 2020, there will be more than 40 million drivers on the road in this age group. Also, in the UK, the IAM Road Safety forecasts that the number of over 65 drivers will increase from 9.5 million in 2004 to 10.4 million in 2011, and to 12.7 million in 2021 [8]. This shows that for the automotive industry, the elderly group is not only becoming more influential in deciding what car to buy, but should also be considered as requiring important services. However, the elderly have not yet taken any beneficial services from the industry despite being a large portion of the driving population. One issue is particularly prevalent in the vehicle repair and maintenance service: Elderly drivers have often paid more money than younger drivers in car-repair garages due to their lack of knowledge of current vehicle systems with modern technologies. Although a lot of vehicle systems have become

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more technically sophisticated for a driver's safety and convenience by incorporating different high technologies, such a complicated system is difficult for elderly drivers to understand and repair. According to the Ripoff Report [18], "National auto service centers company over charges for parts, elderly people most, excessive unneeded work, parts being installed when not needed. The company over charges excessively for auto parts 4.2 over what they pay."

Given this fact, developing a tool to diminish this disadvantage and to help elderly drivers maintain their cars with confidence and with minimal cost is necessary. Although some tools have been created for vehicle repairs, they only provide guidelines via an application or book, and they are not helpful enough for vehicle owners to appropriately repair their vehicles without the help of experts. Drivers should have guidelines to identify a specific problematic component and a system to provide a solution for problematic parts. Additionally, although many automotive companies have updated vehicle system networks to help customers easily use and maintain them, it is still difficult for the elderly drivers to identify vehicle errors and repair their vehicles by themselves. Moreover, even though this is a regular issue, many scholars and developers have not considered training or helping them to avoid potential damage nor have they offered convenient vehicle repair and maintenance services. As a result, there is no product for elderly drivers to benefit from vehicle repair and maintenance, and they can continuously suffer from the same issue. Therefore, first, this paper will investigate challenges for the elderly with modern vehicle systems based on their body conditions and study how detecting vehicle failure modes are complicated and difficult to understand. It will also emphasize the significance of a system concept for the elderly by analyzing current systems and suggesting possible system developments for the elderly based on focus-group survey and interviews. Finally, it will provide proper system feature-concepts for the elderly throughout the focus-group evaluation.

2 Challenges for the elderly using modern vehicle systems

The elderly population face many problems due to their declining body conditions, such as hearing loss, vision and cognitive impairments, late reaction, and other chronic illnesses. Elderly users could also experience differing familiarity in using and understanding high technologies, and their usability could be influenced by the technologies. These barriers can affect how they react to technological systems. Thus, understanding their capabilities and limitations will help scholars and developers create usable application systems for elderly users.

Here are some general problems associated with the elderly that we should address.

Firstly, some eye conditions can interfere with the elderly's ability to focus their peripheral vision and can cause difficulty seeing in the dark or blurred vision and lowered recognition of colour contrast [5]. Poorly sized and coloured components of the vehicle systems can be very frustrating to view. With imperfect visual acuity, they have difficulties in detecting and judging the location of objects correctly [5]. Secondly, decreased hearing is a key symptom of ageing. Sometimes, elderly people experience difficulty hearing higher pitched sounds and separating particular sounds from important auditory cues in the vehicle systems. Thirdly, elderly users may experience reduced dexterity and motor control, making precise system control and accurate movement on the vehicle systems very difficult [21]. Thus, when vehicle systems show abnormal signal patterns due to vehicle system errors, elderly drivers could have a very difficult time responding to the signals.

In addition to sensory problems, elderly drivers often undergo cognitive decline with a loss of short-term memory, becoming more easily distracted, and declining in analytical and communication power, and reading skills [17]. Elderly users might also experience difficulties understanding compound and large amounts of text, and following long and complicated instructions [3]. If a lot of unfamiliar information is displayed on the vehicle system, they could have a higher chance of getting lost when trying to manage the system. Thus, they often become confused and feel helpless when they encounter error messages from vehicle systems. This confusion and helplessness can affect their confidence in using current vehicle systems, and limit their ability to use different systems in the vehicle.

Elderly drivers do not only face a physical and age-related impairment. The different age groups can also pose unique challenges for elderly drivers since they have less experience with modern technology than other age groups [9]. Lack of experience with particular interfaces and systems in the vehicle can make them more difficult to interpret. An owners-manual for user's tutorials is also difficult for the elderly to understand due to a lot of unfamiliar jargon. Thus, elderly drivers can be more fearful to use vehicle systems with modern technology [22].

3 Analysis of current vehicle system modes for detecting vehicle symptoms

Due to age-related conditions and less experience with modern technology, there are many possibilities for this age group to have more financial losses in repairing and maintaining current vehicle systems. With rapidly improved technologies in vehicle electronics, control, and software contents for vehicle diagnostic systems, using and understanding systems has become even more difficult for the elderly users.

To have an accurate and easier detection method in vehicle symptoms, many studies [1, 4, 6, 12, 13, 14, 16, 20, 22] have been introduced in vehicle diagnostic system concepts and networks. However, we still need to find better ways to diagnose vehicle failure modes.

For example, Pattada and Signh [12] introduced a basic diagnostic process based on the Fault Detection and Isolation (FDI) model. In their study, FDI is defined as a subfield of control engineering that concerns itself with monitoring a system, identifying when a fault has occurred, and pinpointing the type of fault and its location. Also, the fault-model-based interactive service procedure tool is discussed as a guidance role in this study. The tool uses a fault model, and is built using service-procedures information, historical repair data, and engineering inputs. This fault model captures dependencies between multiple symptoms, such as Diagnostic Trouble Codes (DTC), vehicle-operational parameters, customer complaints, and technician-test outcomes and relates them to probable faults. In the service bay, this tool employs the fault model and vehicle symptoms to provide a ranked list of suspect components, related repairs, and the next steps necessary to further isolate the fault. In effect, as the technician collects and inputs more symptoms or test outcomes with the tool, it isolates the fault to specific components and recommends further actions until the fault is isolated to one specific component, and then recommends the correct repair. When examining the fault-model-based diagnostic system, this study pointed out one problem. An expert technician who is familiar with service procedures can infer faults and failure modes from DTCs and PIDs and perform correct repairs with a very high probability. But, a less-experienced technician can perform service procedures that lead to a lower probability of correct first-time fixes and increased repeat visits. It would also lead to increased troubleshooting time and increased labour costs. This means that the drawback on this system should be fixed to reduce human errors and a new and supplementary system to appropriately mange the system errors from the fault model inside vehicles should be developed.

Also, Palai [1] mentioned a limitation of existing fault management: Typically, fault-detection techniques are limited to determine whether some fault has occurred or not. The problems associated with the existing practice are that for any given fault, multiple Diagnostic Trouble Codes (DTCs) are registered by multiple Electric Control Units (ECUs), from the central module to the entire system, which results in confusion for service technicians. It does not focus on correctness of the data received from the network nor monitor the root cause of such faults over various vehicle-manoeuvring conditions. This leads to increased time to repair a given fault. Therefore, he stated that a vehicle-level system that supports fault management and a suitable vehicle network should be created.

Given this fact, electric and computer systems play a key role in controlling the fault modes and should properly communicate with diverse modules in the vehicle. Also, such a current system mode could make it difficult to detect and diagnose vehicle errors for users. Therefore, we need to explore and refine better ways to provide a tool for non-experts like elderly drivers, as well as service technicians, allowing them to easily, quickly, and effectively repair and maintain vehicles.

4 A current assistive device for vehicle repair and maintenance

I-Mechanic is the first Augmented Reality application from Inglobe Technology [7] based on an innovative computer vision 3D tracking software for smartphones to support people in ordinary maintenance of vehicles anytime and anywhere. Car engines and equipment can be a totally unknown universe for most of us. Even if a person with significant driving experience is driving in a new car, the person might not know where the most relevant parts in the engine are exactly located. With this mobile application, anyone can contextually access the instructions required to maintain their car, where and when it is necessary. Also, this application can provide a person with useful information on nearby auto repair and parts stores with the opportunity to reach the person in a more effective and contextual way.

This application must be sufficiently good to show people exactly where vehicle errors are located by showing problematic components in the vehicle with a blue mark via a smartphone display. However, it shows only one way to fix the vehicle errors although many causes can exist within one component error. Furthermore, the function of the detection-system application is limited to engine detection, and it only works properly when drivers open the front hood of the vehicle. In addition, it only provides closest auto repair shops without repair and maintenance cost details. Thus, when an elderly driver goes to the store that the system indicates, they may still pay more than they expected, thus repeating the current issue. Therefore, a smart assistive tool should be designed and developed which can detect vehicle errors easily and effectively, indicate them with more effective designs than the current one, and offer diverse ways to repair the errors.

5 Research methods

5.1 Questionnaire study/survey for identifying initial system concepts

Since smartphone ownership among older adults has risen in recent years, their convenient vehicle repair and maintenance service via a smartphone display could make them more easily accessible at an affordable cost. Thus, we decided to design and develop application system concepts considering the physical and mental conditions of the elderly.

To propose an adequate application system concept for the elderly to have a usable vehicle repair and maintenance system, surveys and interviews were conducted with elderly focus group. These short research activities were conducted in Seoul, Korea where many elderly drivers actively drive around the city area. For the first activity, the survey was conducted with 50 participants aged 60-75 with at least 20 years of driving experience and age-related health issues, such as decreased eyesight, lowered memory, and slower reaction times. The survey questions asked about their specific situations when they have vehicle system errors and visit repair and maintenance stores. Based on the short survey questions, interviews were also conducted with the participants. The fifty interviewees were divided into 3 groups: The age of 60-65 (15 persons), 65-70 (15 persons), and 70-75 (20 persons) and the interview session had been taking for 3 hours. Once the survey and interviews were returned, the resulting data were analysed (see Table 1).

From the survey data, we learned that elderly drivers tend to go to auto repair stores at an average of one to three times per month and have vehicle errors predominantly in the infotainment systems. They have difficulty easily recognizing error signals. Particularly, in the vehicle infotainment system, a lapse in recognizing visual signs is often reported in other studies. According to a report from Parker, Reason, Manstead, and Stradling about driving errors, elderly respondents reported more lapses than other full-age-range samples of drivers in the recognition of the visual signs [2]. This fits in with what is known about the declining cognitive capacities of older people and the increasing likelihood of problems with attention. Villalba, Kirk, and Stamatiadis also stated in their study that head-on crashes requiring a driver's visual recognition and search capabilities occurred most in the elderly group [11]. Also, 83% of elderly participants feel afraid when vehicle errors are occurred. The main reason is that they are worried about the money required to pay for repairing vehicle errors. They also said that since

a lot of high technologies have been applied to current vehicle systems, they thought that repairing the vehicle errors would be more expensive than it had been in the past. Some elderly people said that technicians in auto repair stores could overcharge them for repairing services more than other age groups because they have less experience with modern technology in the vehicle and merely know about current vehicle system modes. Also, from the last survey question, 78% of the elderly participants feel that they pay more than they expected and they stated they have difficulty finding a trustworthy repair shop to fix their vehicles for reasonable prices.

Furthermore, the elderly group could not understand technical jargon for the vehicle systems and most of the words are English-based. Thus, they often get lost when technicians are explaining vehicle system errors. Based on the analysis of the survey and interview results, current repair and maintenance services are not effective and beneficial enough for the elderly and need to be improved.

After analysing the survey data of the elderly experiences, the focus group interviews were conducted to establish a repair and maintenance service system for them and the focus group was asked if they had suggestions for an application system that would be more beneficial for their driving life.

Table 1. Survey data from 50 elderly drivers.

Q1	How often do you go to auto repair stores per month?	
	① 0	0
	② 1-3 times	35
	③ 3-6 times	12
	④ Over 6 times	3
Q2	What kind of vehicle error have you had?	
	① Engine	15
	② Infotainment	30
	③ Seating system	4
	④ Lighting Systems	1
Q3	Could you catch error signals in the vehicle well?	
	① Yes	18
	② No	32
Q4	If yes, do you feel afraid when you have errors from your vehicle?	
	① Yes	15
	② No	3
Q4-1	If yes, what makes you nervous from the situation?	
	① Doesn't know why and where the errors are occurred.	4
	② Would pay a lot of money for the repair	6
	③ Where to go for repairing my vehicle	3
	④ Above all	2
Q5	Could you understand when an auto-technician explains your vehicle conditions?	
	① Yes	3
	② No	47
Q6	Do you think that you have paid more than you expected?	
	① Yes	39
	② No	11

5.2 Focus group study on confirming and enriching the initial system concepts

Based on the research, identical application concepts specifically for the elderly could be considered with diverse suggestions from the elderly focus group. Here are some application concept proposals in both design and technological aspects based on the previous research data gathered.

5.2.1 Design aspect

When designing a proper system for the elderly group, there are some elements that should be considered to help them use it without errors. Also, design and technology should be well-collaborated to satisfy and support many elderly drivers. Thus, during the interview session with the focus group, we asked the elderly interviewees what design elements should be considered for the repair and maintenance service application. From the interview results, all elderly drivers complained about text and icon sizes in the current applications. Due to their failing eyesight, their sizes are not big enough to read, so they often can't easily recognize functional menu options in the applications. If the text sizes and icon images enlarged, they would easily perceive the options in the application and would react quicker when another option needs to be processed. Moreover, those with arthritis and swollen fingers can have limited usability to communicate with the applications. A growing number of applications offer numerous multi-finger gestures for new touchscreen interfaces. Those with upper limb and mobility problem could face difficulties in performing different gestures like touch buttons, and controlling sliding functionalities.

According to Ramussem, Pejtersen, & Goodstein[10], "Information presented by the system should be offered in such a way that it can be easily and unambiguously understood without any additional help". So, the iconic images should be carefully simplified with representative images for the elderly.

5.2.2 Technological aspect

Identical application concepts considering diverse technologies for the elderly could be developed with feasible system ideas.

Here are some technical feature concepts based on previous research data.

First, indicating vehicle failure errors throughout the application can allow the elderly driver to easily find problematic parts in the vehicle. The interviewees stated that they have had many experiences when they don't know where the vehicle errors are occurred. So, they just followed a technician's directions, and sometimes required many more repair parts than they thought.

And, a technical function showing closest repair stores with prices of different vehicle components should be created to help the elderly repair their vehicle for a reasonable price. The main complaint from the elderly drivers in the repair and maintenance service is that they pay more than they expected. Most interviewees said that if they have a common repair price list with each vehicle component in the different vehicle models, they could have a chance to negotiate the repair price and select the repair shops within their budget. Thus, detailing the closest stores with comparative repair prices can help the elderly drivers avoid wasting their money on the service.

Lastly, an instruction voice and sound would be helpful for elderly drivers with vision problems. The elderly interviewees indicated that they could not understand current vehicle system manuals because most of the contents are described with small text size and are difficult to find. Thus, most elderly drivers have merely read the manuals although a lot of vehicle information is explained in it. So, if the application has a function to explain each current component audibly, they could understand the vehicle parts more easily and have more knowledge about vehicle systems.

5.2.3 Concept recommendations for the elderly drivers

Based on the previous proposal, we conducted the application concept development for elderly drivers. In this development process, suggested design and technological aspects were developed with diverse concepts. To determine whether the application concepts would be beneficial to elderly drivers, we asked the focus group to evaluate them by rating them on a scale of 1 to 5, with 1 being the minimum and 5 being the maximum. We asked them to rate the concepts using the following criterion: ease of use, frequency, and whether it was a good match for its intended user group. Furthermore, another interview session was conducted to evaluate the usefulness of the application concepts. The focus

group was asked about how often each person would use the application system if it existed and if they had suggestions for other design concepts that would be more beneficial to aid with vehicle repair and maintenance.

6 Results

The data was collected from subjective concept ratings from the elderly focus group and the focus-group suggestions from the interview. From this data, we finalized fine-design concepts for elderly drivers that have the highest ratings in terms of their ease of use, frequency, and whether they are a good match for elderly drivers.

6.1 Designing set of application concepts

To be a properly defined application design concept that is marketable as a future application design for elderly drivers, the sets of design concepts considered their physical conditions and minimized drawbacks of previously proposed design systems.

First, indicating vehicle failure errors were designed with cues on the problematic part, such as a red marking, a red marking with a blinking effect, and a red marking with text description because a blue marking used in the current application is not easily recognizable and the color was not effective enough to draw their attention to the problematic parts.

Second, showing closest stores on the map was provided with two options: showing the store map with different prices and indicating a store with the cheapest price based on the price comparison.

Third, a voice instruction concept was systemized with two functions. With one, all instructions are explained with a voice for all the options and with the other, only a warning sound and voice instructions indicating a problematic part and a way of repair and maintenance were suggested.

6.2 Evaluation of the system concepts and finalized application concepts

After designing the application concepts, the focus group rated them based on previously defined criterion. The rating results are also in Table 2.

Table 2. Designed system concept evaluation.

Proposed Systems for The elderly	**Potential Design Concepts**	**Evaluation**			
		Ease of use	Frequency	Fit for the elderly	Total
Indicating vehicle errors	Red marking	2	3	2	7
	Red marking with a blinking effect	4	3	4	11
	Red marking with text description	4	5	5	14
Informing auto repair shops	Providing a shop on the map with different prices	4	3	3	10
	Providing a shop on the map in the cheapest price	4	4	5	13
Sound function	Voice function for all vehicle components	3	3	4	10
	Voice function for a problematic part with instruction	4	5	5	14

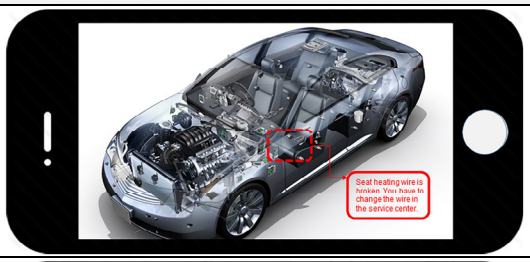
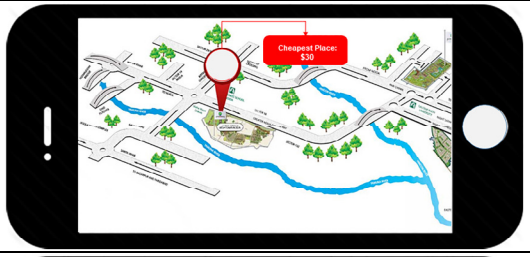
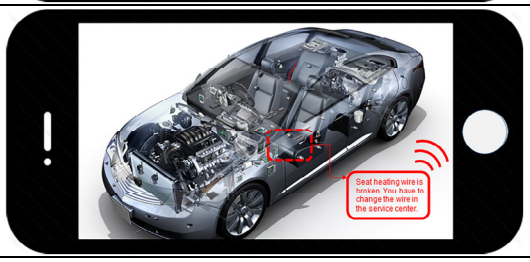
After rating each concept from the focus group, the final preferred application concepts were suggested. From the final systems, we can see how each concept has affected the focus group conditions. The final concepts are shown in the Table 3.

First, indicating vehicle failure error with a red marking with a test description was selected by the focus group. The elderly focus group said that they mostly want to know what kind of problem their vehicle has. If the application shows a red marking with text on a problematic part, they would easily

recognize where to repair. However, if there is only a marking with a colour or blinking cue, sometimes they would be confused or misunderstand where the problematic part is since many vehicle systems are connected with each other. Also, elderly focus group suggests a different colour marking on the problematic part based on a level of severity for that part. For example, a red marking would indicate that a vehicle owner should repair the system as soon as possible and a yellow marking means that there is a symptom on a certain part that requires attention at some point.

Second, providing an auto repair shop with the cheapest price was more preferable for elderly drivers because they don't want to check all the stores for different prices. Particularly, selecting and showing the cheapest repair price would be very effective for elderly drivers with diminished memories and vision. Several elderly people said that the closest shops with different prices might give them more opportunity to select a shop. However, if they check all the prices in the stores, they stated feeling dizzy and too stressed to choose. Also, the focus group proposed that proving the shop's pros and cons with the cheapest price would be more beneficial for them when selecting a repair shop.

Table 3. Designed system concept evaluation

Proposed systems for the elderly	**Finalized design concepts**	**Feature**
Indicating vehicle errors	Red marking with text description	
Informing auto repair shops	Providing a shop on the map in the cheapest price	
Sound function	Voice function for a problematic part with instruction	

For the sound function, a warning sound on a vehicle error and explaining how to repair the erroneous parts was chosen from the focus group. They said that if they have too much information for the part, they can not remember everything due to their memory deficits. Knowing only basic, essential information would be enough for them. They suggested that a voice explanation should be operated with Stop, Rewind, Fast Forward, and Start options because they need to carefully check if they miss the name of problematic parts, where the parts are located, and how to repair the parts. Also, the elderly focus group said that if both voice explanation and text are used at the same time, they would feel more confident to use the system and would be able to understand difficult jargon for vehicle systems.

7 Conclusion

In this paper, we analysed the drawbacks of existing vehicle detection modes and application systems and highlighted the significance of system design based on a particular user group, i.e. the elderly. We also surveyed and interviewed 50 elderly people to identify their repair and maintenance difficulties and gain insight into what type of application systems would be most beneficial to them. Finally, we proposed and developed essential application concepts that the focus group needs and that could mitigate issues the elderly currently have and provide a convenient and enjoyable maintenance experience. However, a limitation of our study was that the application concepts for the elderly group were not fully tested with an actual vehicle system. The finalized system concepts could be changed from actual tests. In future work, we would test how the finalized concept works for the elderly group.

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